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c. Final Technical Report.

The archived data from the SAS-3 observations of the X-ray nova A0620-00, the best of the stellar blackhole candidates, were exhaustively examined for evidence of variable phenomena correlated with the orbital motion of the binary system of which it is a member. The original analysis of these data was completed before discovery of the binary companion and determination of the orbital period of the system. New interest was drawn to the task of a reexamination of the archive data by the recent discovery of the massive nature of the X-ray source through analysis of the Doppler variations and ellipsoidal light variations of the faint K-star companion by McClintock and Remillard. The archive research, carried out under the supervision of the principal investigator, was the topic of the thesis submitted to the MIT Department of Physics by Kenneth Plaks in partial fulfillment of the requirements for the degree of Master of Science.

Plaks' effort was focused on the elimination of fluctuations in the data due to errors in attitude solutions and other extraneous causes. The first products of his work were long-term "light curves" of the X-ray intensities in the various energy channels as functions of time during the time from outburst in August 1975 to quiescence approximately 6 months later. These curves, shown in Figure 1, are refined versions of the preliminary results published in 1976 (Matilsky et al. 1976).

Smooth exponentials were fitted to these long term light curves to provide the basis for "detrending" the data, thereby permitting a calculation of residuals derived by subtracting the fitted curve from the data. The residuals were then analyzed by Fourier analysis to search for variations with the period of the binary orbit, namely 7.75 hours. No evidence of an orbital periodicity was found. However, the refined light curve provides a much clearer picture of the outburst and subsequent decay of the X-ray luminosity. In fact, there were two outbursts, each followed by an exponential decay with similar time constants of about 25 days. Previous evidence of a three-oscillation variation with a 7.8 day period were confirmed.

Substantial theoretical effort has been devoted to attempts to account for the decay characteristics as the result of the gradual "eating up" of an accretion disk by a stellar-mass blackhole (e.g. Huang and Wheeler 1989). The improved decay curves will provide significant new constraints on the theoretical analyses.

The results of this archive research, together with the results of previous archival research on the spectral characteristics of A0620-00 by Una Hwang will be incorporated in a journal publication currently in preparation.

References

- Huang, M., and Wheeler, C. 1989, *Ap. J.*, **343**, 229.
Matilsky, T., Bradt, H. V., Buff, J., Clark, G. W., Jernigan, J. G., Joss, P. C., Laufer, B., and McClintock, J. 1976, *Ap. J. (Letters)*, **210**, L127.

Appendix A. Abstract, Conclusion and key figures from the 1991 thesis of Kenneth Plak.

(NASA-CR-186715) A SEARCH FOR PERIODICITY
IN THE X RAY SPECTRUM OF BLACK HOLE
CANDIDATE A0620-00 Final Technical Report
(MIT) 10 p

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FINAL REPORT
NASA GRANT NAGW-1694

b. Final Property Inventory

No items of equipment were purchased under this grant.

d. No patents and no inventions resulted from the work performed under this grant.

A Search for Periodicity in the X-Ray Spectrum of Black Hole Candidate A0620-00

by

Kenneth Plaks

Submitted to the Department of Physics on June 1, 1991
in partial fulfillment of the requirements for the degree of
Master of Science in Physics

ABSTRACT

Using archival data from the MIT X-Ray Observatory on board the SAS-3 satellite, we have produced refined X-ray light curves of the X-ray nova A0620-00 during its initial outburst and subsequent decay. We use data from similar observations of the Crab Nebula to generate elevation dependent response functions for the SAS-3 detectors and to develop objective criteria for perfecting the A0620 data in the energy ranges 1.3 - 5 keV and 5 - 13 keV. We then analyzed the A0620 light curves and the hardness ratio for evidence of periodicity. In particular, we searched for evidence of the 7.75^h orbital period found in optical observations by McClintock and Remillard (1986). Using a Monte Carlo simulation, we showed that the 3 σ upper limit on the amplitude of oscillation in the hardness ratio is 3.2%. We also searched for the 7.8^d period reported by Matilsky *et al.* (1976). We found three cycles of a 7.8^d oscillation in a 22 day section of the data with a $\sim 40\%$ amplitude. However in the remainder of the data, in excess of 200 days, we were able to place 3 σ upper limits on the intensity amplitude of 2.2% before the section and 7.3% after. We therefore find no evidence to substantiate a persistent 7.8^d period. We conclude that the system exhibits little to no persistent X-ray periodicity at any frequency. We also conclude that high inclination angle models of the system where the accretion disk is fed via Roche lobe overflow are not appropriate.

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4.3 Conclusions

In chapter 4.2 we derived upper limits on the periodicity of the X-ray spectrum of A0620. For the 7.75^h period we found that the 3σ upper limit on the amplitude is 4.17% in the A channel ramp. We showed that apart from one twenty day period, the 3σ upper limit on the amplitude for the 7.8^d period is 7.3%.

It is perhaps not surprising that we see no evidence for the 7.75^h optical orbital period. This period was determined by MR through photometric and spectroscopic observations. There are no eclipse phenomena. One credible mechanism which might impress this period onto the X-ray spectrum is electron scattering from a high density electron cloud. If matter is accreting via Roche lobe overflow, we expect such a cloud near the L1 point where the streaming matter impacts into the accretion disk (figure 4.3).

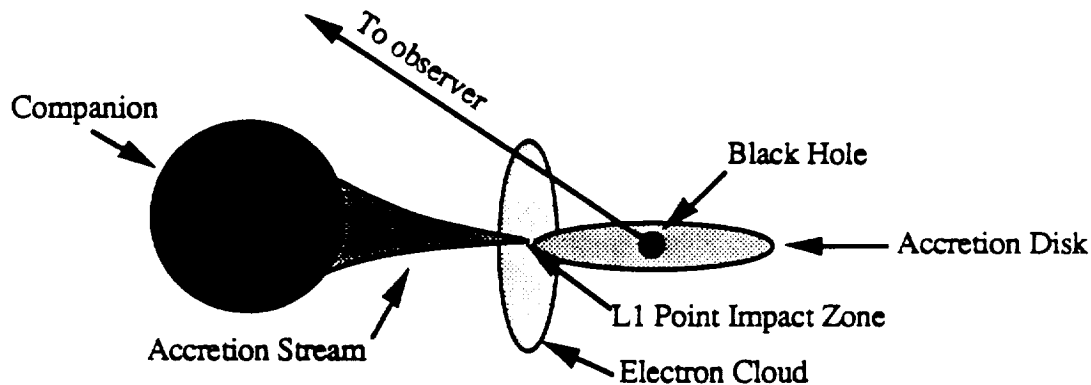


Figure 4.3: Diagram of electron cloud from the impact of the accretion stream into the accretion disk softening photons in observer's line of sight.

These electrons would scatter the X-rays and soften the resultant spectrum. Checking the B/A hardness ratio would reveal this softening to us. We expect to see this scattering during the decay phase of the nova when mass flow rates

are high. If we saw such periodicity it would imply that the system was accreting via Roche lobe overflow and that we were at a fairly high inclination angle with respect to the binary plane (chapter 1, figure 1.1) The fact that we see no evidence for this periodicity suggests that either the system is accreting via Roche lobe overflow, but is not at high inclination angle, or that the system is accreting via stellar wind capture at any reasonable inclination which satisfies the no eclipse condition. The severe hardness ratio amplitude 3σ upper limit of no more than 3.17% tends to rule out high inclination Roche lobe overflow models.

The light curves we obtained are extremely smooth. They are nearly perfect exponential decays (Figs. 4.2.1 and 4.2.2). Both of the non-steady state accretion theories presented in Chapter 1.3 predict such a decay. These theories are therefore in good agreement with our results.

We confirm the existence of three oscillations of a 7.8^d period between 7 January, 1976 and 13 February, 1976 previously reported by MB in the same data. This section of the data exhibits an amplitude of approximately 40% in the A channel. However, by virtue of our improved data reduction based on analysis of Crab observations detailed in chapters 2 and 3, we were able to show that in the rest of the data set, in excess of two hundred days, the A channel has a 3σ upper limit of 2.15% before this section and after it the 3σ upper limit in the A channel is 7.3%. The twenty two day section consists of three dips and three rises and could be represent 3 cycles of a 7.8^d period. It could also be three dips and three rises of interesting, but periodically insignificant, morphology in the X-ray light curve. We therefore find no evidence to substantiate the existence of a persistent 7.8^d period.

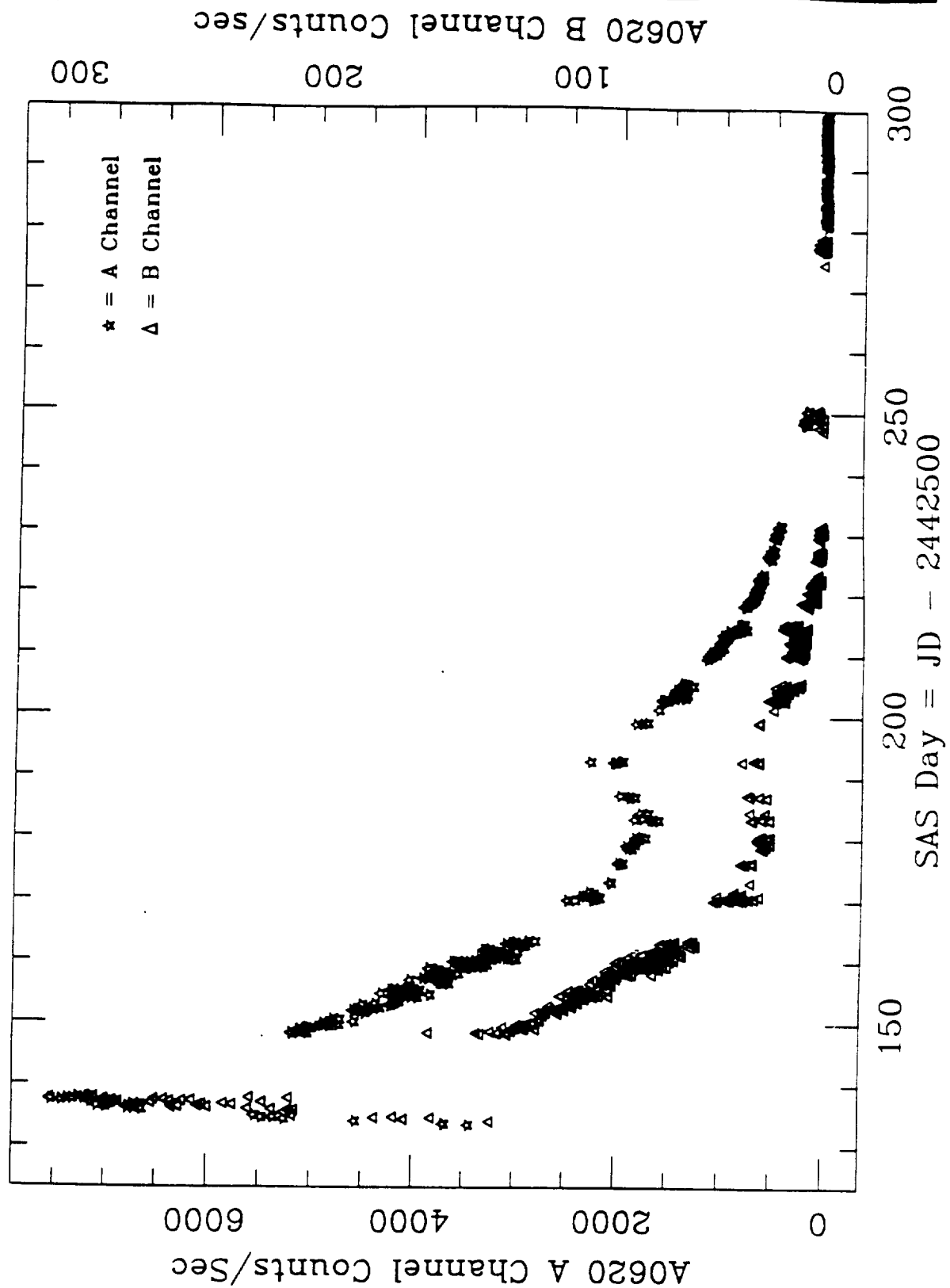


Figure 3.3: (c) Center Slar A and B channel plotted together.

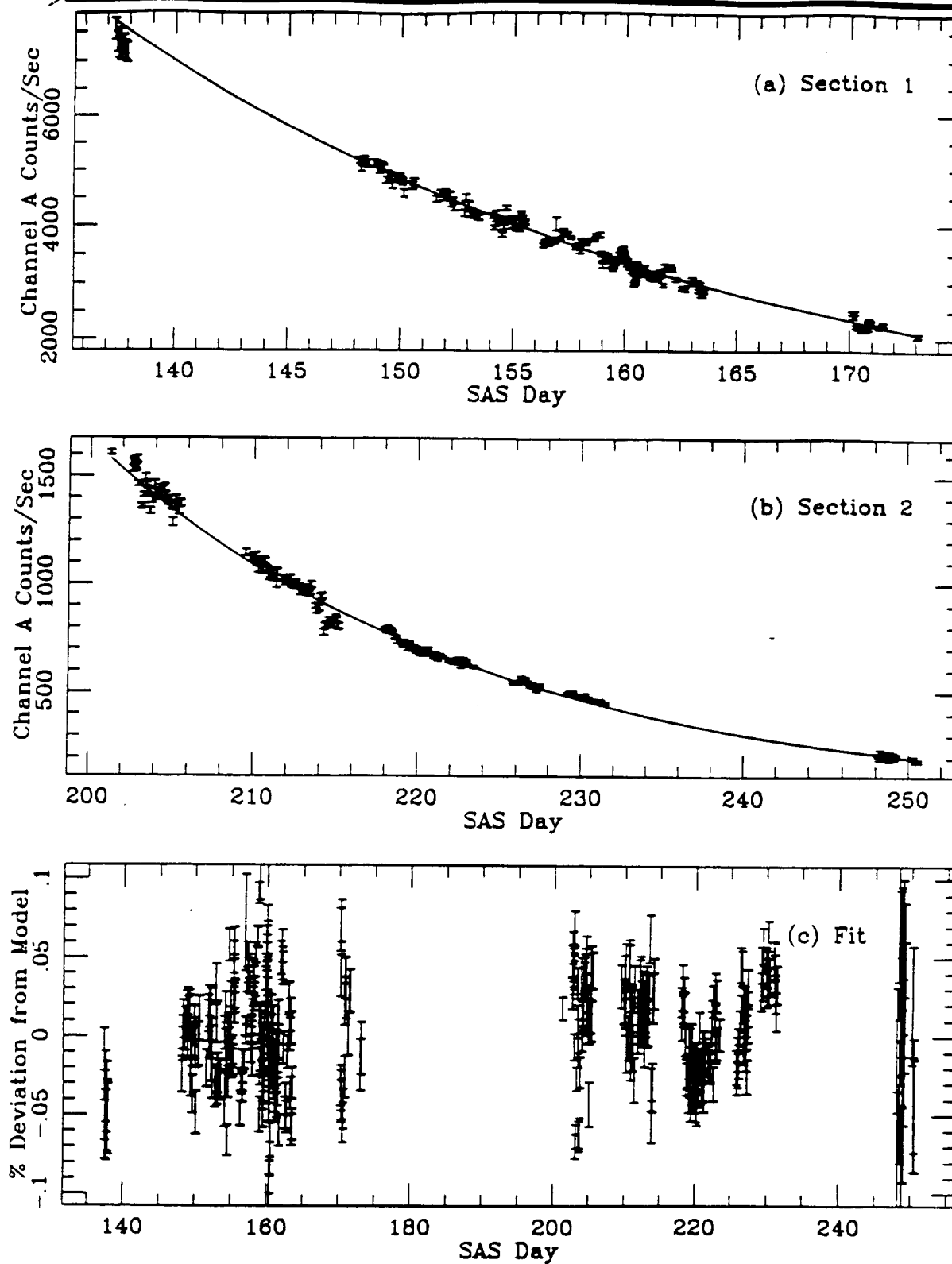


Figure 4.2.1: (a) Channel A fit for SAS days 137 - 175. Curve is best fit exponential.
(b) Channel A fit for SAS days 200 - 255. Curve is best fit exponential
(c) Combined percent deviations from models.

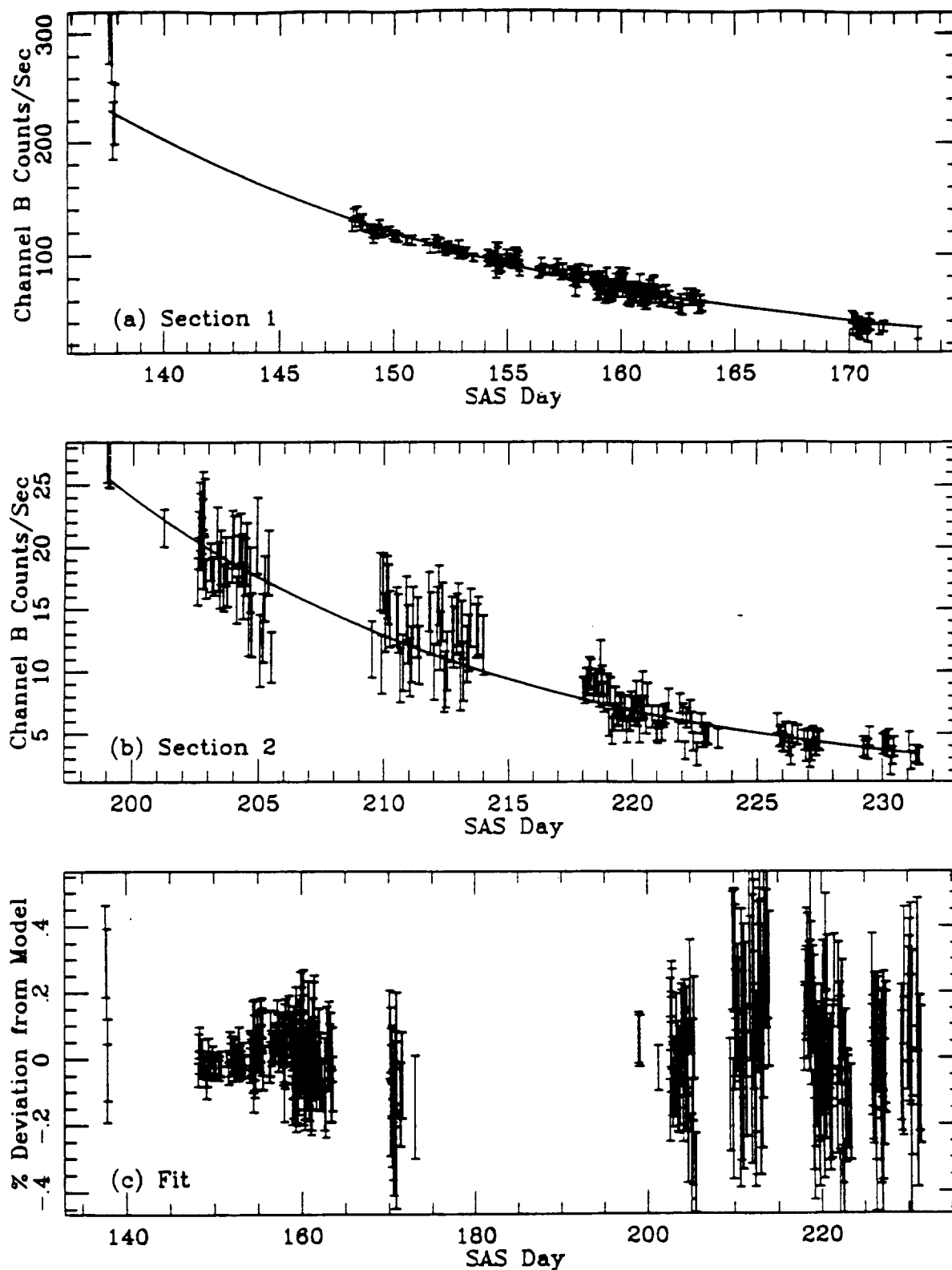


Figure 4.2.2: (a) Channel B fit for SAS days 137 - 175. Curve is best fit exponential.
(b) Channel B fit for SAS days 200 - 255. Curve is best fit exponential
(c) Combined percent deviations from models.

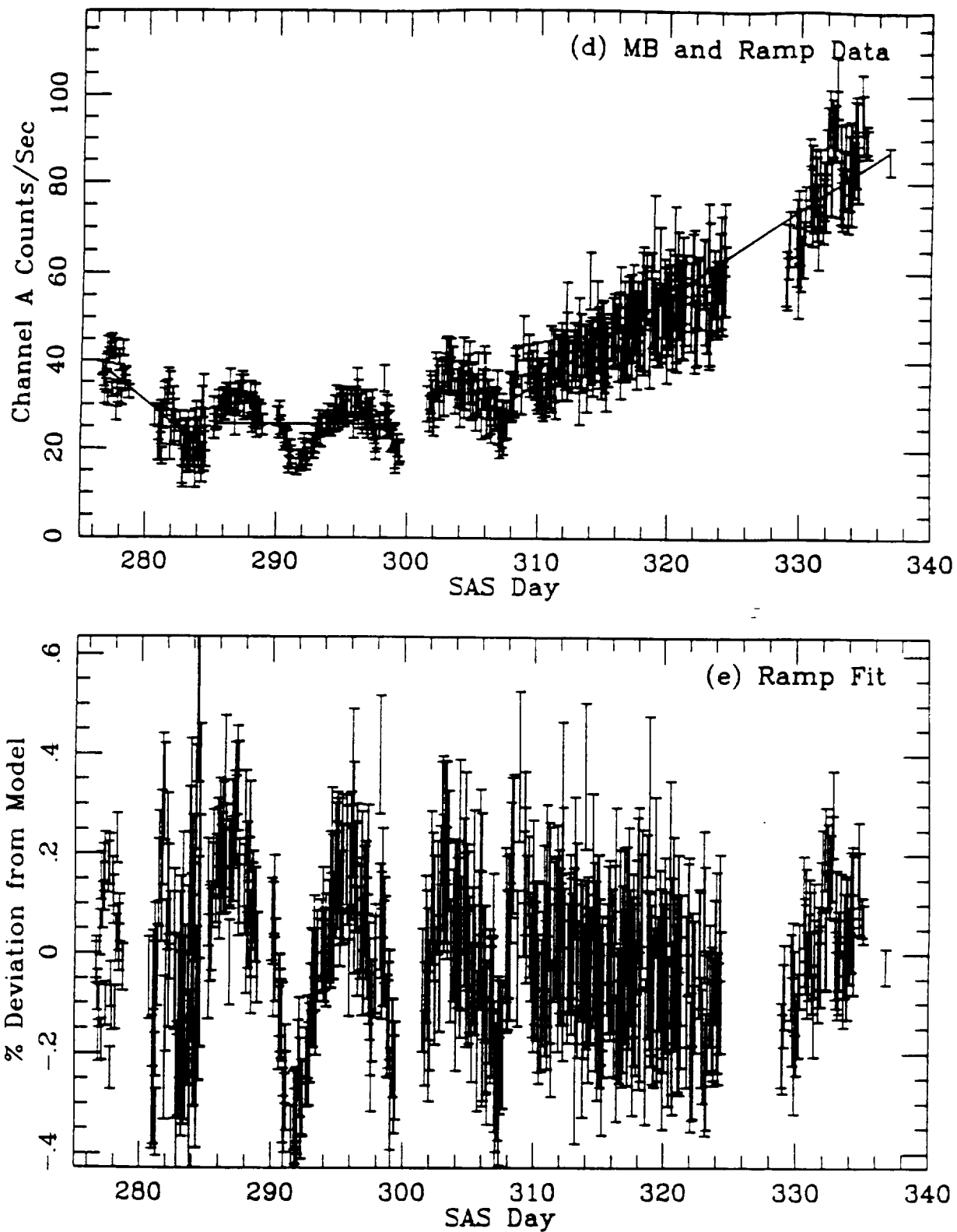


Figure 4.2.1: (d) Channel A fit for SAS days 275 - 340. Curves are best fits as described in text.
(e) Combined percent deviations from models.

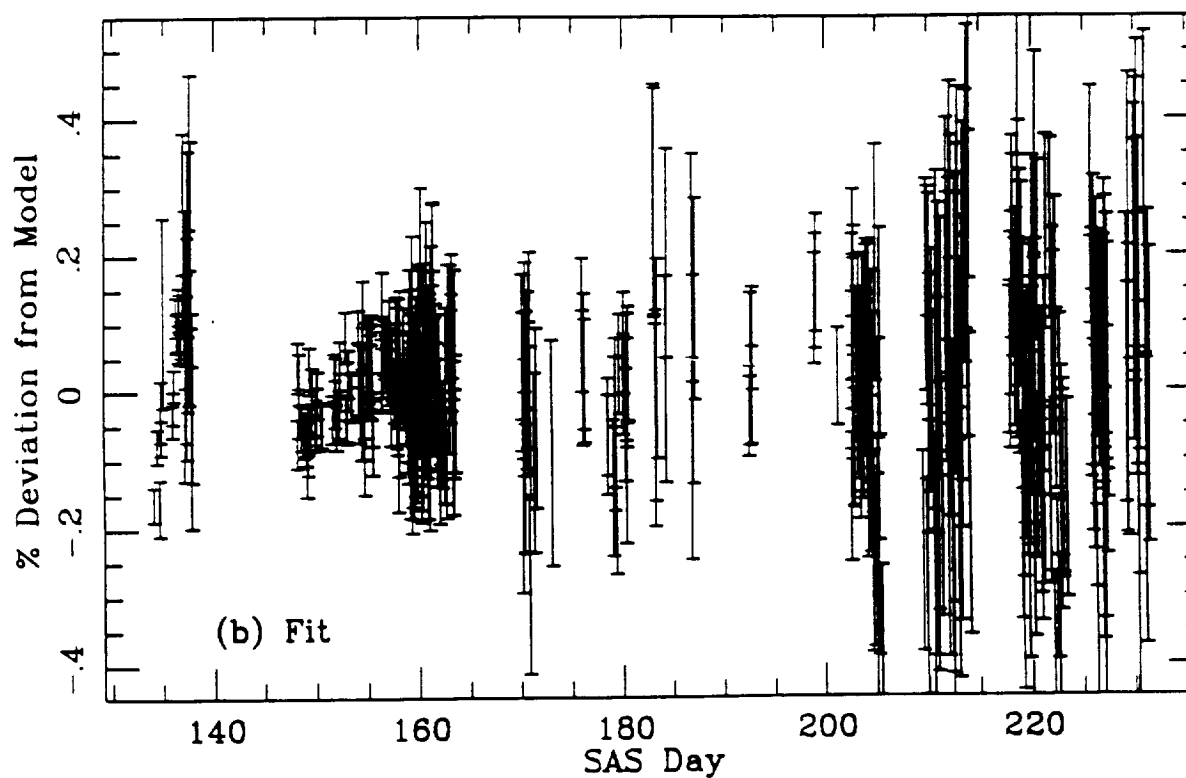
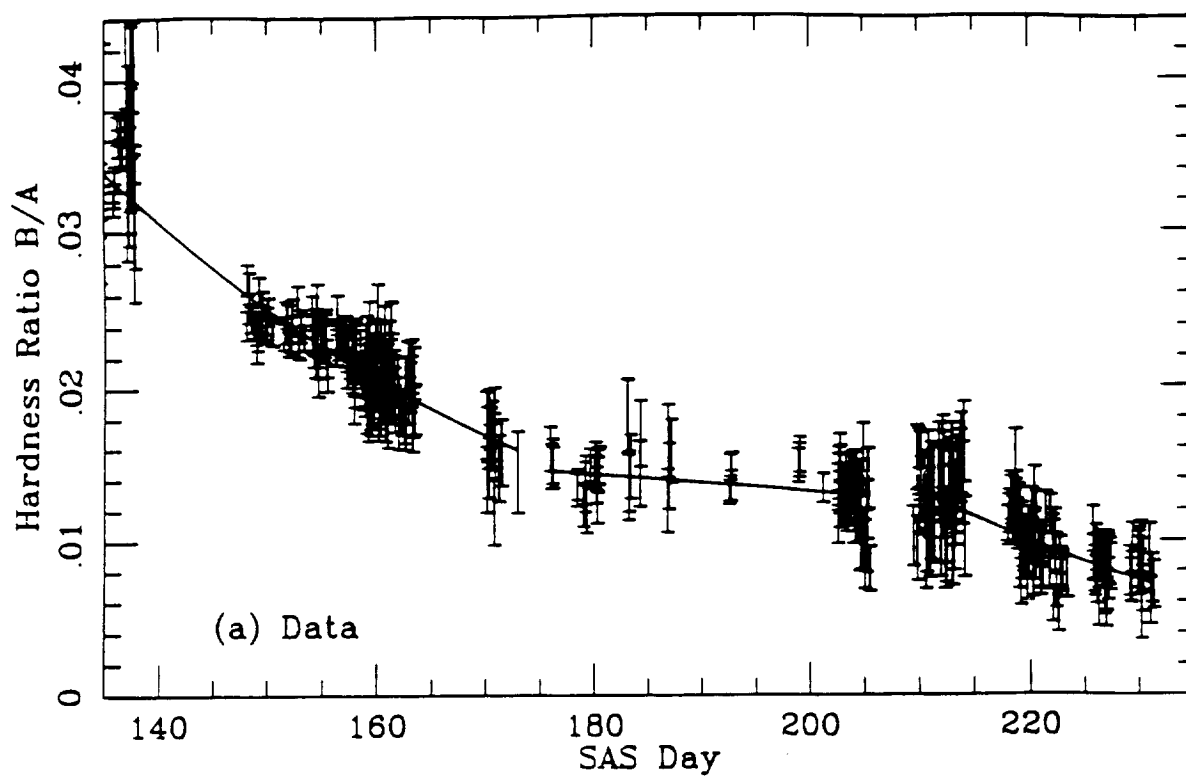


Figure 4.2.3: (a) Hardness ratio fit for SAS days 135 - 240. Curves are best fits.
(b) Combined percent deviations from models.